

THE CHEMICAL UTILIZATION
OF
MUNICIPAL WASTE

E. K. HAMMOND

ARMOUR INSTITUTE OF TECHNOLOGY

1909

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The chemical utilization of
municipal waste

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THE CHEMICAL UTILIZATION
OF
MUNICIPAL WASTE

A THESIS

Presented by

EDWARD K. HAMMOND

to the

PRESIDENT AND FACULTY

of

ARMOUR INSTITUTE OF TECHNOLOGY

For the Degree of

BACHELOR OF SCIENCE IN CHEMICAL ENGINEERING

Having Completed the Prescribed Course

of Study in

CHEMICAL ENGINEERING.

1909.

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I N T R O D U C T I O N .

The development of a municipality has in all ages been marked by the appearance of certain problems, which are indicative of the degree of refinement attained in the city under consideration.

Three of these problems may be regarded as typical and mentioned in the order of their importance they are:-

1st, The provision and maintainence of a sanitary water supply.

2nd, The construction of a sanitary sewer system.

3rd, The satisfactory disposal of municipal waste. The first and second of these difficulties have fallen to the lot of the civil engineer for solution while the third, after receiving considerable attention from various sources, has at the present time reverted to the somewhat modern profession of Chemical Engineering and it is the purpose of this paper to discuss in detail the method of proceeedure which is apparently the most satisfactory one yet devised.

The attention of the writer was first called to this question thru his acquaintance with Mr. Charles Turner, President of "The Chicago Reduction Company", the firm which has charge of the disposal of refuse for the city of Chicago, and while considering the

question of a subject for a thesis, "The Chemical Utilization of Municipal Waste" seemed both suitable and instructive. The choice of this subject was further recommended by the courtesy of Mr. Turner, who gave permission to study the methods in vogue at the Chicago Plant and furnished samples of the products, from the different stages, of the process, for Chemical examination in the college laboratory.

After considering the subjects which should properly be included in the discussion of the disposal of municipal waste, the writer has decided to divide his paper into four parts, as shown in the following outline.

Part I.

1. The classification of municipal waste.
2. The methods of collection.

Part II.

1. General discussion of methods of disposal which have been adopted previous to the development of the "Reduction Method".
2. The factors which were active in bringing forward the "Reduction Method".

Part III.

1. Technical discussion of the "Reduction Method".

Part IV.

1. Financial discussion of the "Reduction Method".

Part I.

Municipal waste may be divided into two general subdivisions, (1) household waste, (2) street waste, while each of these general subdivisions may be further classified as shown in the following table.

Table I.

			Vegetable matter
		Garbage	Animal matter.
			Meat and bones.
			Fruit and vegetables.
	Household		
	Waste.	Ashes.	Paper and rags.
Municipal			
Waste.		Rubbish	Leather and rubber.
			Wood.
			Bottles, crocks, cans, etc
			Sweepings.
Street			
	Sweepings.		Manure.
Waste			Droppings from carts.
			Building material.
			Dead Animals.

A brief consideration of Table I. will be sufficient to show the variety of the material which has to be dealt with under the heading of Municipal Waste and this diversity in the nature of the material has been one of the chief obstacles in devising a satisfactory method of disposal. To obviate this difficulty a system known as "primary separation" has been put into effect by the ordinances of those cities, such as Chicago, New York and Cleveland Ohio, where the best systems of disposal are used. This system requires the separation of household waste into the three components shown in Table I., namely:- Ashes, garbage and rubbish, by the householder and that these three components be placed in separate recepticals ready for their removal by wagons making periodical rounds for this purpose. In this way the question of disposal is far less complicated, since the material to be treated is somewhat homogeneous, and the results obtained have shown a most gratifying improvement.

The collection of garbage has been still further improved by the use of specially designed wagons, the body of which consist of a closed box made of sheet steel, the purpose being to reduce any odor nuisance to a minimum.

Part II.

The methods of waste disposal which were, and are, in use previous to the development of the "Reduction Process" may be divided into two general groups. Those of the first group are applicable to all the classes of waste mentioned in Table I. while those of the second groups are special methods of disposal devised for application to specific types of waste. There are six methods of disposal which are sufficiently important to demand mention and these appear in the following list accompanied by the class of material to which each method is applicable.

Group I.

Methods applicable to all classes of waste.

1. Dumping on land.
2. Dumping in water.
3. Incineration.

Group II.

Methods applicable to special classes of waste.

4. Feeding to swine. This method has been carried out with the better grades of garbage.
5. Ploughing into soil. This method has been applied to garbage and street sweepings.
6. "Reduction". Applicable to garbage.

Methods one and two have very little to recommend them and unless the dump where method one is applied is far removed from human habitation or the water where method two is applied has fixed conditions of tide or current to carry away floating material, serious complications may result from a sanitary point of view.

Methods four and five are open to criticism from a financial standpoint as it is evident that they are only open to application at points far removed from a city and consequently the expense involved in hauling the material to the point of disposal would be excessive. Method six, which is undoubtedly the best of the group, will be described in detail in Part III. of this paper.

Method three, incineration, is undoubtedly the second in point of general efficiency, being only exceeded by the more modern method of reduction and where the quantity of waste to be treated is relatively small this method finds favor where its powerful rival reduction is excluded owing to the high first cost of the plant required to carry out the reduction process.

A typical form of incineration was that devised by Mr. A. M. Brainerd to dispose of the refuse of Chicago. This furnace was constructed at Superior St. and the river in 1891 and may be briefly described as follows:- The wagons conveying the refuse to the incinerator were driven up on to a platform where the load was dumped opposite the entrance to three chutes. The material was transferred from the platform to these chutes by hand and passed down by gravity into the furnace. The products of combustion from the furnace passed up the chutes and entered the main flue a short distance from the entrance. By this arrangement the moist constituents of the waste, such as garbage, were dried and the entire mass was partially consumed before reaching the bed of the furnace. This consisted of a cylindrical chamber about eight feet in diameter and twelve feet in height. A working door was provided just above the grate bars of the furnace in order to provide means for stoking, which was a very important factor in the successful working of the incinerator. The combustion was facilitated by means of oil which was sprayed in by means of a steam jet and by a forced draft furnished from a circular pipe surrounding the base of the kiln.

No attempt was made at this time to utilize the heat produced for the generation of steam although this might readily have been done by means of either the fire tube or the water tube type of boiler. Aside from this possible source of revenue the system had many points in its favor. It was capable of handling all types of waste with equal facility and the temperature maintained in the incinerator was so high that the combustion of all organic matter was complete before it issued from the stack thus precluding the possibility of any objectionable odors causing a nuisance in the neighborhood of the incinerator. This last feature enabled the final disposal of the waste to be carried out by this method at a point quite close to the vicinity in which it had been collected thus cutting down the expenditure for teaming to a minimum. The residue left in the incinerator was an ash which was always in demand for filling and could be disposed of without the expense of hauling away.

The only draw back to this method of disposal lay in the fact that the material which was being burned in large quantities every day contained a considerable per centage of valuable constituents.

The other methods described were, of course, open to this same criticism and it was to save these valuable components of the waste matter that the Chemical Engineers of the country began to work along the line of the "Reduction Process", about the beginning of this century.

Even at the time of writing, however, with the knowledge we have of the saving involved by reduction, it cannot be too strongly emphasised that, unless the amount of waste to be treated is sufficient to warrant the construction of a large reduction unit, the incinerator is by far the most satisfactory method of treatment, especially when provision is made for the generation of power from the heat developed in the combustion chamber, as it has been found that small reduction units cannot be profitably operated.

Part III.

We have seen from the six methods of disposal previously mentioned that some attempt was made to use garbage and street sweepings as a fertilizer but this attempt was crude and the expense of hauling was excessive owing to the fact that the material, containing about 82% of useless moisture and 3% of valuable grease was hauled long distances in this form in order to utilize the fertilizing properties contained in the remaining 15% of the material.

Before entering upon the discussion of the reduction process it will be well to consider the chemical composition of an average raw garbage as it comes to the reduction plant.

Table II.

Analysis of raw garbage.

Moisture	82%
Grease	3
Tankage	<u>15</u>
Total	100

The tankage contains materials possessing values as fertilizers in the amount shown below:-

Ammonia	3.76%
Phosphoric acid	1.47
Potash	1.87

A study of table II. brings forth the following conclusions:- The raw garbage contains a large amount of water, which is useless and adds very seriously to the expense involved in hauling, and a relatively small percentage of grease and valuable fertilizing materials, which would, however, assume some appreciable figure if they were considered on the basis of a sample freed from moisture. These were the prime factors which led to the development of the "Reduction Process" for it was apparent that if the raw material

was deprived of the moisture it contained the residue could be handled with much greater facility and still contain its original value as a fertilizer, while the extraction of the grease would add a considerable source of revenue without detracting from the benefit derived from applying the resulting tankage to the soil.

Two general methods of treatment are in use for the reduction of garbage and street sweepings. By the first method the refuse is subjected to a drying process by passing it thru rotary kilns, which are heated by the products of combustion from gas or coal furnaces, and the grease contained in the residue is then extracted with naphtha. The residue is sold to fertilizer plants as a filler for fertilizer. This method gives satisfactory results except that during the drying process the fumes which are liberated from the stack are most objectionable. The second method of procedure obviates this difficulty. The raw material, to be treated by this method, is charged into steel cylinders where it is treated for a period of eight hours with steam under a pressure of fifty pounds per square inch. These cylindrical tanks are provided with vent pipes at the top which lead to a condenser and any foul smelling vapors, which may be produced are

condensed before being discharged into the sewer. During this treatment the walls of the cell which contain the fats present in the garbage, are broken down and during the subsequent pressing treatment, to which the material is subjected, any fat present is squeezed out along with a considerable amount of water, from which it is easily recovered by skimming, after it has been allowed to cool sufficiently to solidify. The residue remaining in the press is known as "tankage" and, this is dried and sold for fertilizer filler as mentioned above under the naphtha method.

Considering the two methods of reduction from every point of view it appears that rendering by steam is the most satisfactory. In the first place a properly operated plant, of correct design, may be conducted with the production of very little objectionable odor and this method of reduction is further recommended by the fact that the danger of explosion of naphtha is avoided. Another item in favor of steam rendering is that the steam consumed might be generated from the heat produced by the combustion of rubbish in an approved type of incinerator.

After a careful consideration of the subject the writer decided to select this method of procedure and the subsequent part of this paper will be devoted to the design of a plant to handle 250 tons of garbage

125 tons rubbish and 375 tons of street sweepings per day, in a town where primary separation is enforced, so that the various materials come to the plant in separate conveyances.

The ground plan of the entire plant is shown in figure 1, and the operating of the various elements composing it may be described as follows:-

Disposal of Rubbish and Street Sweepings.

The wagons bringing rubbish and street sweepings to the plant discharge their loads in the yard indicated in figure I, and the material is then moved onto the conveyors by men using forks. This conveyor leads to the charging hopper over the incinerators and passes a platform on which four men are stationed to remove all saleable material, such as rubber, leather and the better grades of paper and rags, as it moves by them. This part of the work is usually done by the employes of a separate firm, which has contracted with the reduction company for the privilege of removing the desirable portions of the rubbish at a stipulated sum, based on the amount of material taken. The price paid is about \$1.50 per ton and the results of this system in New York have shown that an average of 40%

by weight or 60% by volume of the total rubbish coming to the incenerator will be taken by the trimming contractor. The remaining rubbish and street sweepings pass on to the charging floor of the incinerator.

The average results obtained at the incinerators, which are giving the most satisfactory results at present, show that the consumption per square foot of grate surface per hour is about sixty pounds of rubbish. Using this as a basis and bearing in mind that 40% of the total rubbish is removed by the trimmers, we shall have the total grate area required to be equal to
$$\frac{(375 \pm 60\% \times 125) \times 2,000}{60 \times 24} = 625 \text{ sq. ft.}$$

It will be shown later that sixteen boilers are required. This gives the area of each grate to be $\frac{625}{16} = 39.1 \text{ sq. ft.}$ In designing the boiler setting and grate shown in figure 2, the dimensions of the grate are taken as 6' wide x 7' long. The working doors of these furnaces are large, owing to the bulky nature of the fuel and every fourth furnace is provided with a door 4' x 6', in which the regular door of 18" x 24" is mounted as shown in the detail accompanying figure 2.

The ash resulting from the combustion is free from all putrescible matter and hence it is applicable for filling purposes in conjunction with the ash collections which have been gathered throughout the city.

The heat generated by the incinerators is utilized by a Battery of one hundred hours power boilers of the return tube type, similar to the one shown in figure 3.

It has been found that the heating value of the rubbish, which comes to the incinerators now in operation, shows certain seasonal changes and it is the purpose of figure 4 to show these changes graphically. The minimum evaporative value of 1.3# steam per pound of rubbish burned will be sufficient to generate 1,170,000# steam which is greater than the total required for the operation of the plant.

Taking 1.5# as the average evaporative power of one lb. of rubbish, it will be possible to generate $(375 \pm 60\% \times 125) 2,000 \times 1.5 = 1,350,000$ lbs. of steam from the combustion of the sweeping and useless rubbish coming to the plant.

Since one boiler will generate 3,500 lbs. of steam per hour it will be necessary to provide $\frac{1350000}{3500 \times 24} = 16.1$ which will be taken as 16 for the total boiler complement.

Garbage Disposal.

The garbage wagons dump their loads in the yard indicated in fig. 1, and the garbage is carried by four bucket conveyors to the level of the third floor of the "rendering house". The bucket conveyors dump their loads at this point, on to horizontal wing conveyors which run directly over the digesters. These conveyors have gates situated directly over the charging holes of the rendering tanks, which may be opened as desired to fill the successive tanks. These tanks are similar in design to the one shown in figure 5. They are charged to the level shown, which will make the volume of the garbage contained equal to $\frac{\pi \cdot 6^2}{4} \times 9 + \frac{1}{3} \frac{\pi \cdot 6^2}{4} \times 3 = 264$ cubic feet.

The garbage has an average heaviness of 40 lbs. per cubic foot. This will give the capacity of each rendering tank as $264 \times 40 = 10,600$ lbs or 5.3 tons.

It will thus be necessary to provide $\frac{250}{5.3} = 47.2$ or 48 as the total complement of rendering tanks. The 4" pipes entering at the bottom, the steam pressure being regulated by check valves so that it exceeds a maximum value of fifty pounds per square inch.

At the temperature so maintained about 280.2 °F. it will require eight hours to complete the dendering process. The reactions produced by this treatment are of a physical rather than a chemical nature, in so far as the recovery of the grease is concerned, and consists of the destruction of the cells which contain the grease so that the latter may be readily expressed during the next step in the process.

The crude garbage coming to a reduction plant will have a composition very similar to the result of an analysis made on a sample taken at the plant of the "Chicago Reduction Company", which is given below.

Moisture	68.55%
Grease	3.76
Ammonia	1.72
Ash	26.03
Total	100.06

The ash was analyzed for phosphoric acid and potash and the percentage of these two constituents based on the original sample was:-

Potash (K_2O)	.58%
Phosphoric acid (P_2O_5)	.67%

The rendering tanks are provided with 1/4" vent pipes which carry away any objectionable odors, which may be produced during the rendering process, along with the exhaust steam to a set of jet condensers where the entire volume is liquefied before being discharged into the sewer. The condensers are of any standard type.

After the completion of the rendering process the steam is turned off and the material discharged from the rendering tanks into vats located on the first floor of the "rendering house". After allowing the "tankage" to cool for some time it is filtered thru a standard type of filter press having platens of 4' x 5'. There will be twelve such presses required to handle the quantity of material treated during the day.

The liquor coming from the presses is run into cooling tanks where it is allowed to stand until the grease it contains has solidified at the surface when it may be removed by skimming and barreled for shipment.

A sample of the grease recovered at the plant of the "Chicago Reduction Company" by the naptha extraction process showed the following:-

Analysis:-

Specific gravity	.899
Melting point	27.2°C.
Index of refraction	1.4576 at 40° C.
Iodine number	48.53
Volatile fatty acids	5.62%
Insoluble " "	47.62%
Soluble " "	36.24%
Saponification number	176

The sludge left in the filter presses is taken by a bucket conveyor to the drying machines. These machines consist of horizontal cylinders surrounded by a steam jacket and connected with jet condensers. By this means the evaporation of the moisture retained, in the tankage is accelerated, owing to the reduced pressure maintained by the condenser and at the same time any noxious vapors are condensed before being discharged into the sewer. A shaft passes thru the drying cylinder which carries a number of arms and when this shaft is caused to revolve by means of suitable belting the arms stir up the tankage and expose fresh surfaces to the drying action of the heat applied from the steam jacket.

The dried tankage is ground to a fine powder and is then removed to inclined screens thru which it passes into hoppers, from which it is drawn to box cars for shipment. The final product is a dark brown in color and has an odor somewhat similar to roasted coffee. As it has been deprived of all putrescible matter it cannot be objected to from a sanitary standpoint.

The analysis of a sample of tankage taken at the plant of the "Chicago Reduction Company" is given below.

Moisture	8.20%
Grease	2.10
Ammonia	3.88
Potash	1.59
Phosphoric acid	1.78
Ash	28.27

Steam Consumption.

The following list shows the various steam consuming elements of the plant.

1. Radiation losses from boilers.
2. " " " rendering tanks.
3. Discharge from rendering tanks.

4. Discharge from dryer.

5. Steam used for power.

Assuming that the loss of heat due to radiation, from an unprotected boiler surface is 2.8 B.T.U. per hour, per sq. ft. of exposed surface, per $^{\circ}\text{F}$. difference of temperature between the boiler and the surrounding atmosphere, we shall have a loss from sixteen boilers 5' 6" in diameter x 18' long, equal to $16 \times 2.8 (18 \times \pi \times 5.5 \pm 2 \pi \frac{5.5^2}{4}) \times 24 \times (358^{\circ} - 75^{\circ}) = 16 \times 2.8 (358.6 \times 24 \times 283 = 109,000,000$ B.T.U. Since it requires 1108 B.T.U. to convert one lb. of water at 212°F . into one lb. of steam at 100# pressure we shall have the loss due to radiation equal to the loss of $\frac{109,000,000}{1,108} = 98500$ lbs. of steam.

The loss from 50 rendering tanks 6' diameter x 16' high at a temperature of 280.8°F . or 50# per sq. in. pressure is $50 \times 2.8 (\pi \times 6 \times 10 \pm 2 \times \frac{1}{2} \times \pi \times 6 \times 4.24) \times 8 \times (280.8 - 70) = 50 \times 2.8 \times 268 \times 210.8 = 61,000,000$ B.T.U. This is equivalent to the loss of $\frac{61,000,000}{1032.8} = 59,000$ lbs. of steam during the rendering period of eight hours.

The total steam passed thru the rendering tanks during an eight hour day is,

$$50 F \sqrt{2 gh} =$$

$$50 \times \pi \times \frac{.25 \times}{144 \times 4} \sqrt{2 g \times \sqrt{\frac{50 \times 144}{.036}}} =$$

550 cubic feet per second =

57500 lbs. of steam.

Allowing one and one half tons of steam per ton of tankage dried we shall have,

$1.5 \times 2,000 \times 80\% \times 250 = 300,000$ lbs. steam used in the drier if the crude garbage lost 20% of its weight in the drying and pressing operations, which is about the condition which might be expected.

The power used to drive the conveyors and the agitator of the drying machines will aggregate about thirty horse power and will mean an expenditure of about 21,600 pounds of steam. Arranged in Tabular form the consumption of steam appears below.

Total steam available from the combustion of rubbish is 1,350,000 lbs. The steam consumption of the plant appears below.

1. Radiation loss from boilers 98,500#
2. " " " rendering tanks 59,000
3. Discharge from rendering tanks, 512,500

4. Discharge from dryers	300,000
5. Power	<u>21,600</u>
Total	1,051,600#

This gives a surplus of 298,400 lbs. of steam which might be used for creating forced draft for the incinerators, were such a prodeedure found to be advisable, or it might be used for the generation of power.

Part IV.

Value of the Recovered Products.

The sources of profit from the operation of the rendering plant just described will consist of the recovered grease, the tankage and the saleable components of the rubbish.

The grease is listed under the heading of "Brown Grease" and has a value of from 3 to 4 1/2 cents per lb. with an average of 4 cents per lb. This will give a yearly revenue of $365 \times 250 \times .03 \times 2,000 \times 4 = \$219,000$. The value of the tankage varies according to its freedom from grease and is based upon its components of ammonia, phosphoric acid and potash. It will have an average value of \$3.75 per ton. This will give the value of the tankage recovered as $365 \times 250 \times .15 \times 3.75 = \$51,500$.

Taking \$1.50 per ton as the probable price available on a "trimming contract" for the portions of the waste removed there would be a profit of,
 $365 \times 40\% \times 125 \times \$1.50 = \$27,400.$

This will give the probable yearly income as follows:-

5,470,000 lbs. brown grease @ .04 per lb.	219,000
13,700 tons tankage @ 3.75 per ton	51,500
18,250 tons saleable rubbish @ 1.50 per ton	27,400
Total	<u>297,900.00</u>

The cost of labor for the plant would be about as follows:-

Manager	\$2500.00
Day Dhift.	
Foreman	\$1200.00
Watch Engineer	1200.00
Chemist	900.00
8 Stokers	7200.00
1 Pipe Fitter	900.00
40 Laborers	25900.00
4 Clerks	3600.00

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4 Clerks	3600.00

Night Shift.

Foreman	\$1200.00
Watch Engineer	1200.00
8 Stokers	7200.00
40 Laborers	<u>25900.00</u>
Total	76400.00

Depreciation of Plant - per year

Boilers 5% per year	1600.00
10% on Conveyors	546.00
10% on rendering tanks	2000.00
10% on dryers	400.00
Piping	<u>50.00</u>
	2996.00
Insurance	835.00
Taxes	<u>1666.88</u>
	2501.88
Expenditures	1000.00
Repairs	1000.00
Investment in Plant.	
Value of land	\$300,000.

Building

76100 cu. ft. of reenforced concrete @ 65¢ per	
cu. ft.	49,500

180,000# structural steel @ 3 1/2' per ft.	6,300	
40,000 feet of lumber @ \$30 per M.	<u>1,200</u>	
	57,000.00	
Stack	20,000.00	
16 - 100 H. P. boilers	32,000.00	
48 rendering tanks	21,600.00	
550' 4" pipe	137.00	
793' 1/2" pipe	39.80	
72 4" globe valves	275.00	
48 1/2" " "	27.00	
1025 feet bucket conveyor	1750.00	
200 " apron "	1250.00	
1450 " wing "	1810.00	
1000 " " "	600.00	
4 Grinders	700.00	
4 Sieves	500.00	
	Total	<u>4376880.00</u>
Rubbish hopper	750.00	
Tankage "	750.00	
Dryers	4000.00	
2 Condensers	1200.00	
4 - 5 H. P. steam engines	1400.00	
Office flxtures	500.00	
Tools etc.	500.00	
	Total	266,688.00

Gross profits	297,900
Outlay	85,497.88
Net profits	212,402.12

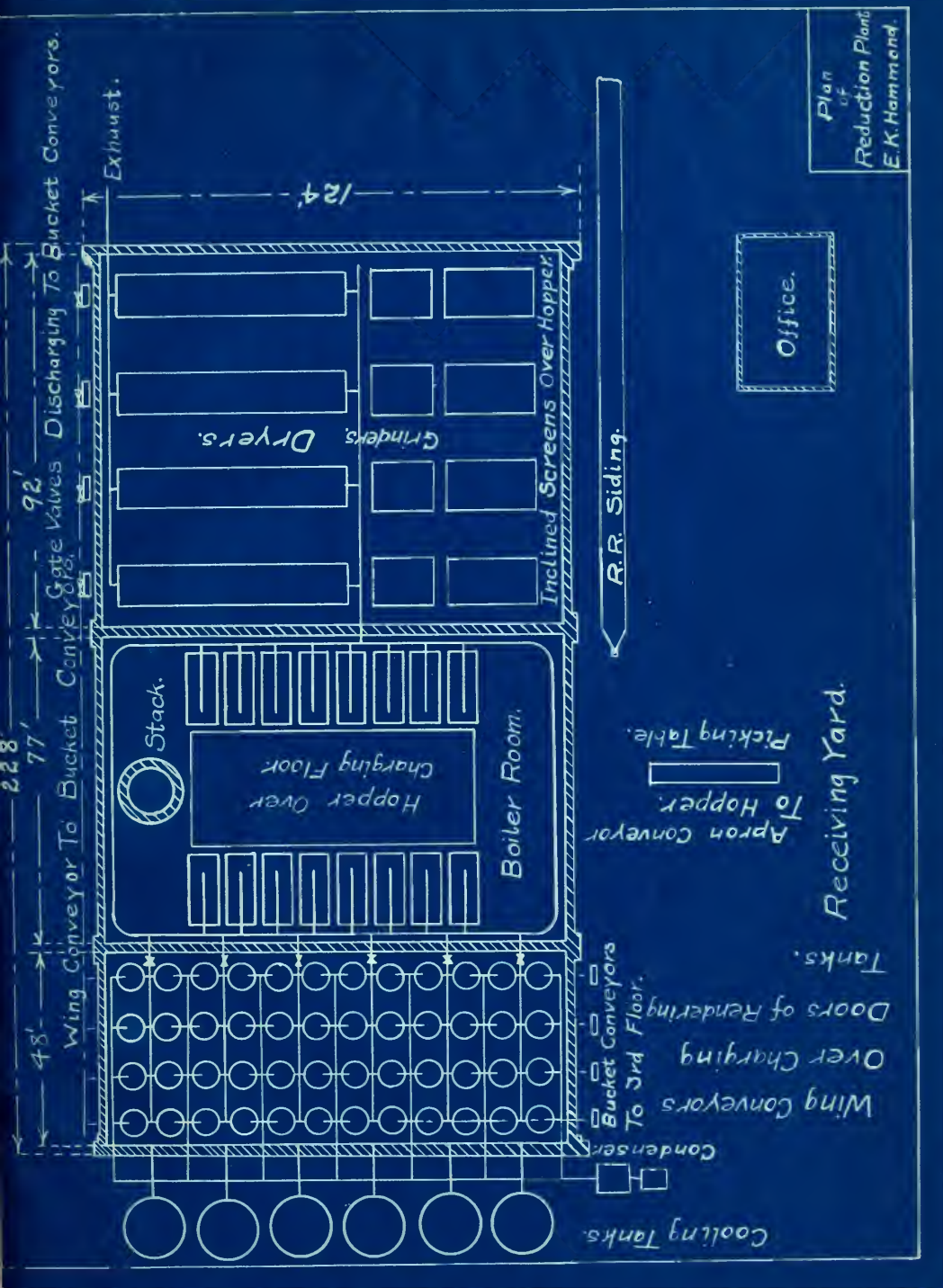
This would give a net yearly profit of 40% on the outlay of capital involved.

It would appear from the figures quoted above that the Reduction method of disposal is a most desirable method of procedure. It is to be feared, however, that the writer has inadvertently taken the position of demonstrating the qualities of the method described and in so doing has stated conditions in too favorable a light. This is possibly the case in the conditions selected for steam generation as there seems to be considerable diversity of opinion regarding the adaptability of refuse for fuel purposes. The results obtained in New York, however, would tend to support the assumptions previously made regarding the caloric power of the combustible portions of the waste.

The value of the recovered products is so considerable, however, that a very wide margin could be allowed for fuel, to be used for steam purposes, and still leave a profit to warrant the adoption of this method in preference to any of those previously described.

Figure I.

Ground Plan of the Plant.

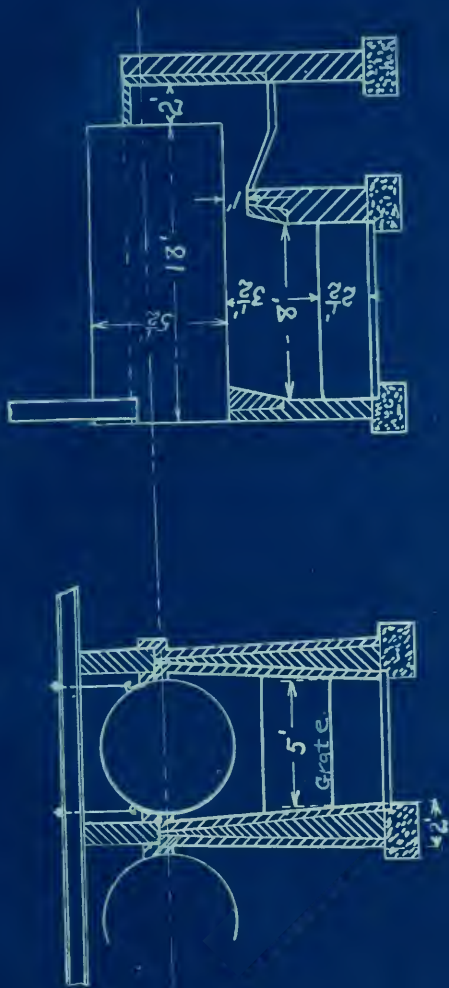


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Figure II.

The design of the incinerator grates.

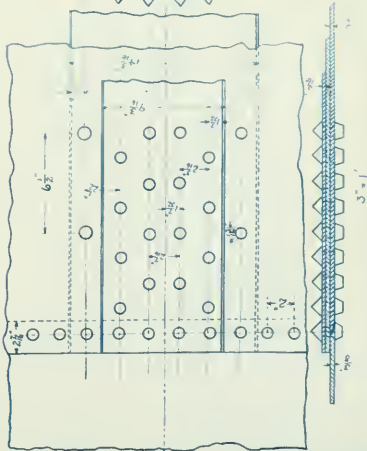
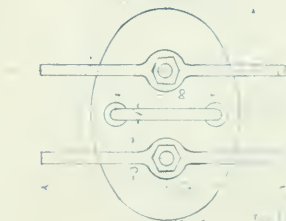
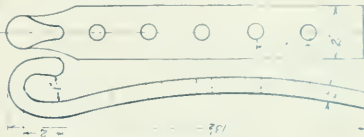
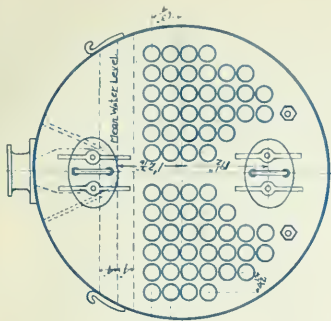
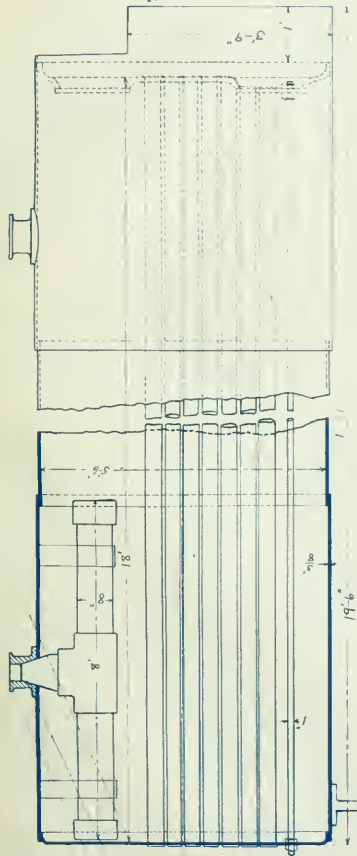
The Masonry between the boilers has a course of fire brick exposed to the flame while the central portion is of ordinary red brick as indicated in the sketch. The brick work rests upon a foundation of concrete as shown and the boilers are suspended from I.beams placed across the brickwork as indicated.



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Figure III.

Design of Return Tubular Boiler.



BILL OF MATERIAL		
No.	Name	Mat. Steel
6	Supporting Hook	Steel
2	Manhole Covers	Steel
68	Fire Tubes 18"x4"	Steel
2	Boiler Heads 18"x4"	Steel
4	Flanges 6"x6"	Steel
2	Dry Pipe 18"x4"	Steel
4	Manhole Braces	Steel
2	Tie Rods 18"x4"	Steel
2	Nozzles 6"x7"	Steel
2	Butt Straps 6"x7"	Steel
2	Rivets	Steel

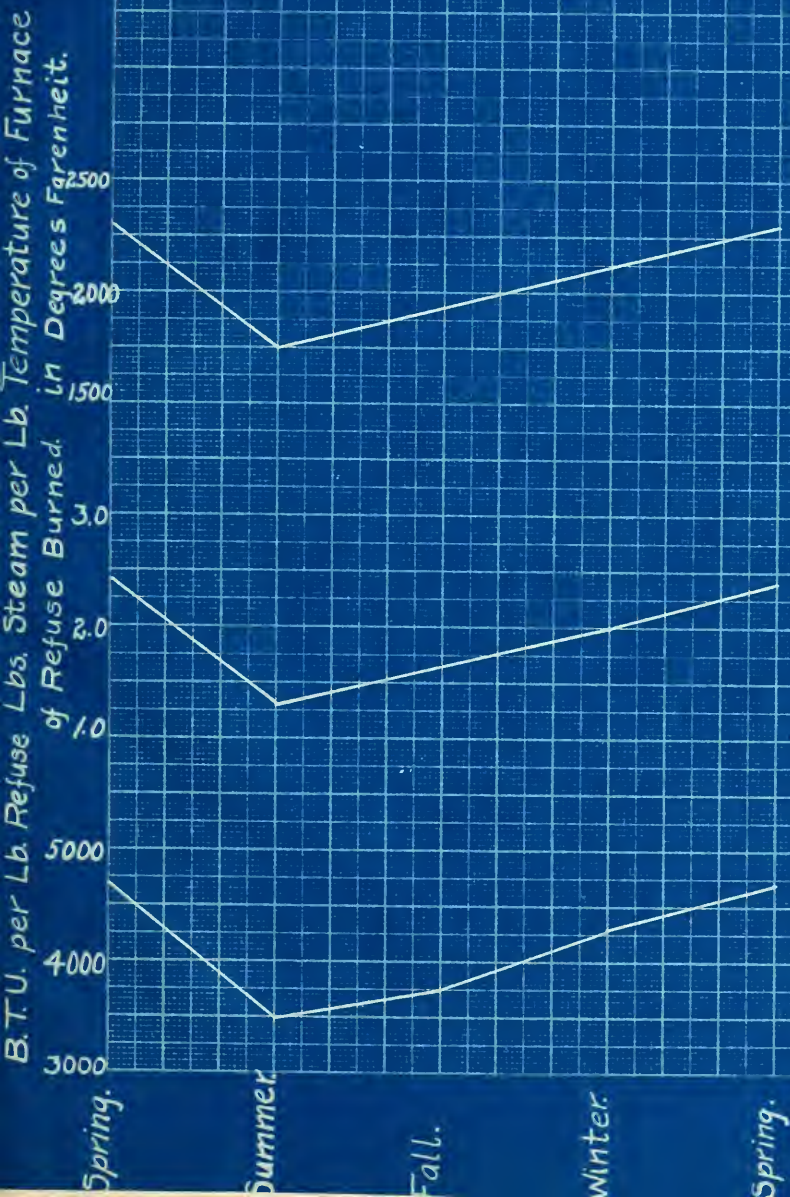
DESIGN
OF
H.P. BOILER
AS PER U.T.C. 1914
AS ADOPTED 5/1/14
E.H. Diamond

AGRICULTURE
INSTITUTE OF TECHNOLOGY
DUBLIN

Figure IV.

Curves showing seasonal changes in the heating value of refuse coming to the incinerator.

Figure 4.



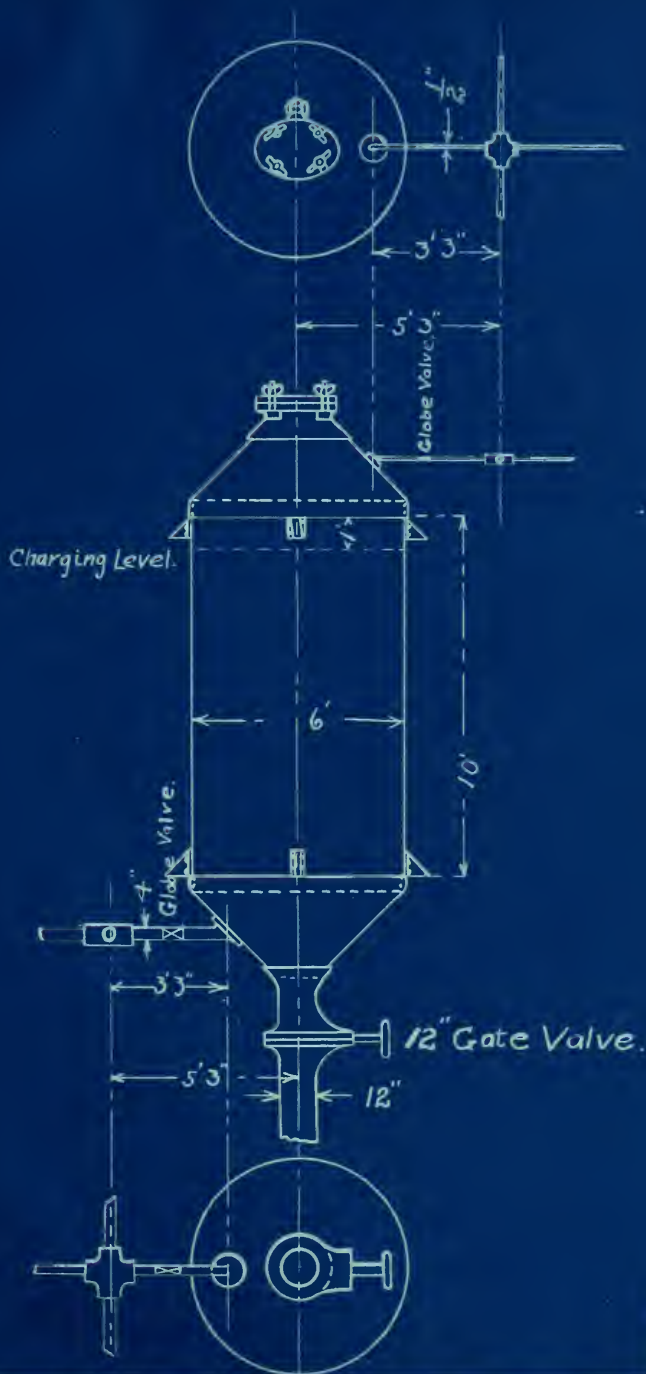
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Figure V.

Design of Rendering Tanks.

These tanks are constructed of three eighths inch boiler plate with standard double riveted lap joints. They are supported by lugs, riveted to the plate and resting upon the steel I beams in the second and third floors.

Globe valves are placed in the steam and exhaust pipes so that any tank may be shut off without crippling the system.



Design
of
Rendering Tank
E. K. Hammond.

ARMSTRONG
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